AGU2016
#H23F-1621

Utilizing the Vertical Variability of Precipitation to Improve Radar QPE

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Abstract Characteristics of the melting layer and raindrop size distribution can be exploited to further improve radar quantitative precipitation estimation (QPE). Using dual-polarimetric radar and disdrometers, we found that the characteristic size of raindrops reaching the ground in stratiform precipitation often varies linearly with the depth of the melting layer. As a result, a radar rainfall estimator was formulated using D_m that can be employed by polarimetric as well as dual-frequency radars (e.g., space-based radars such as the GPM DPR), to lower the bias and uncertainty of conventional single radar parameter rainfall estimates by as much as 20%.

Polarimetric radar also suffers from issues associated with sampling the vertical distribution of precipitation. Hence, we characterized the vertical profile of polarimetric parameters (VP3)—a radar manifestation of the evolving size and shape of hydrometeors as they fall to the ground—on dual-polarimetric rainfall estimation. The VP3 revealed that the profile of Z_{DR} in stratiform rainfall can bias dual-polarimetric rainfall estimators by as much as 50%, even after correction for the vertical profile of reflectivity (VPR). The VP3 correction technique that we developed can improve operational dual-polarimetric rainfall estimates by 13% beyond that offered by a VPR correction alone. .

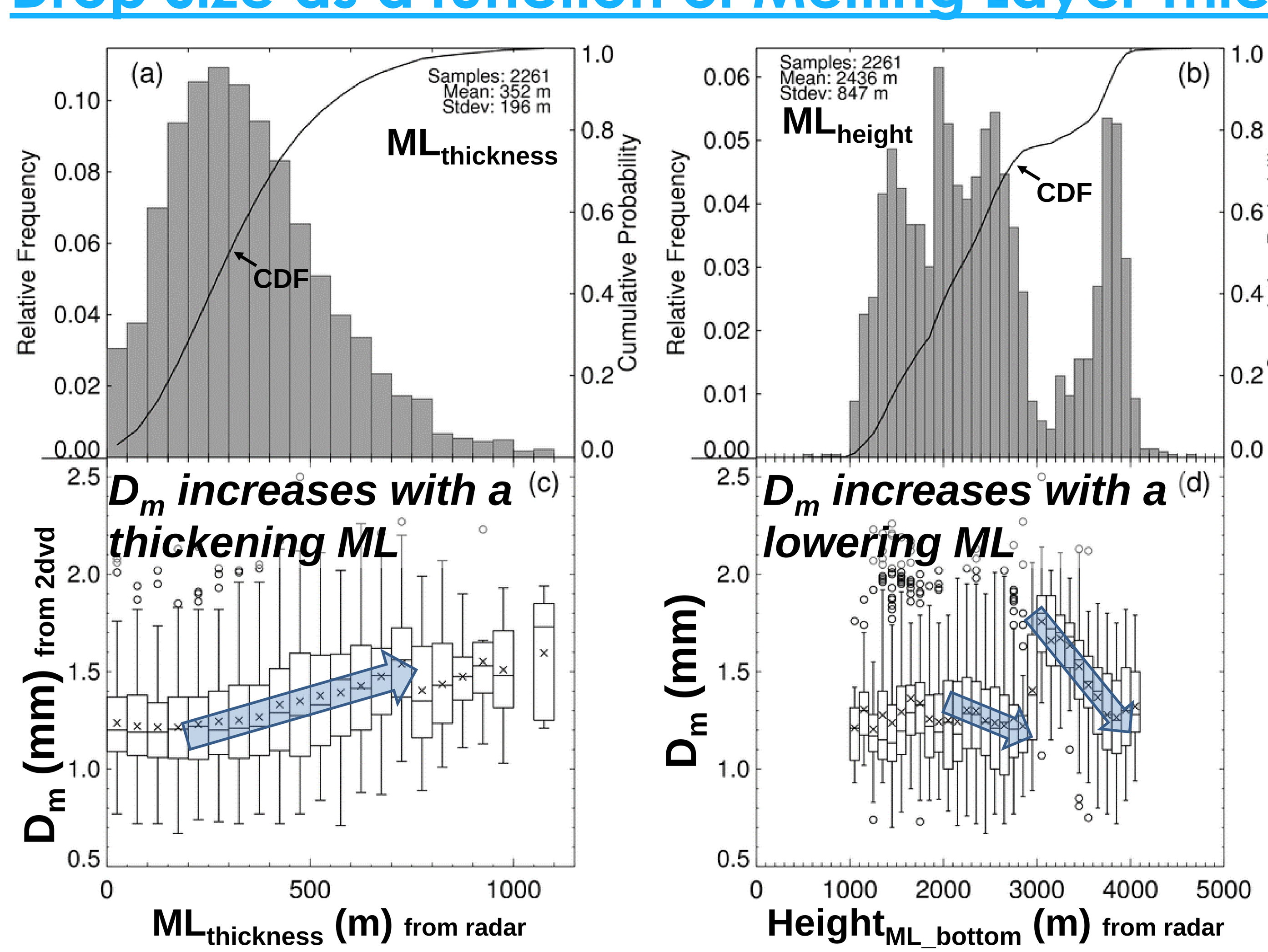
Huntsville, Alabama

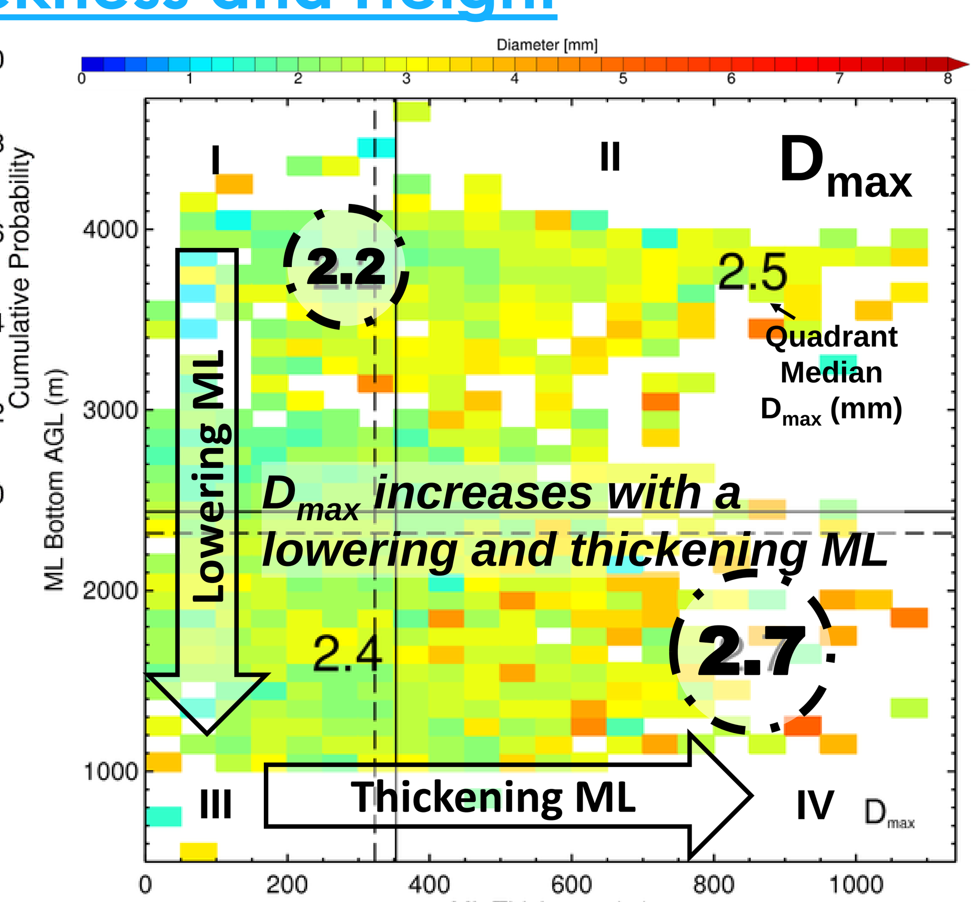
IFloodS (northeastern Iowa)

Radar configuration for RHI sampling over disdrometers

ARMOR	Distance from disdrometers: 15 km
Frequency	5625 MHz (C-band)
Peak transmitted power	350 kW
Pulse duration	0.8 µs
Pulse repetition frequency	1200 Hz
Number of samples per bin	128
Beamwidth (3 dB)	1.07°
Antenna	3.7 m diameter; Center Feed Parabolic
Range resolution	125 m
Polarization	Simultaneous Transmit/Receive of h and v
NPOL	**Distance from disdrometers: 30 km**
Frequency	2790-2810 MHz (S-band)
Peak transmitted power	850 kW
Pulse duration	0.8 µs
Pulse repetition frequency	1100 Hz
Number of samples per bin	72
Beamwidth (3 dB)	0.95°
Antenna	8.5 m diameter; Center Feed Parabolic
Range resolution	150 m
Polarization	Simultaneous Transmit/Receive of h and v

Drop Size as a function of Melting Layer Thickness and Height





→ Drop size increases as ML thickens and as it lowers

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Vertical Variability of the DSD below the Melting Layer

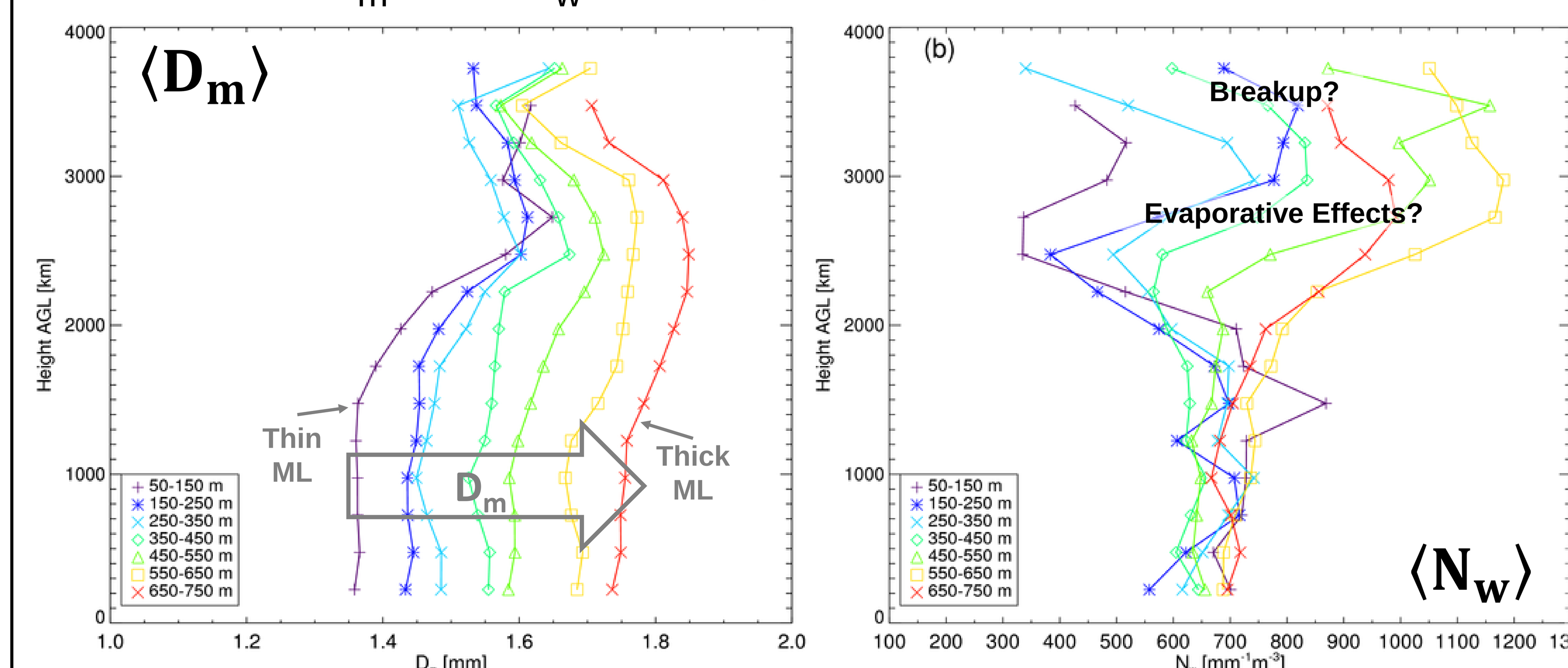
- Normalized Gamma DSD:

$$N(D) = N_w f(\mu)\left(\frac{D}{D_m}\right)^{\mu} \exp\left[-(4+\mu)\frac{D}{D_m}\right]$$

- T-matrix scattering simulations
- Retrieve D_m and N_w from 2,530 RHIs

ARMOR/NPOL DSD Retrieval Uncertainty

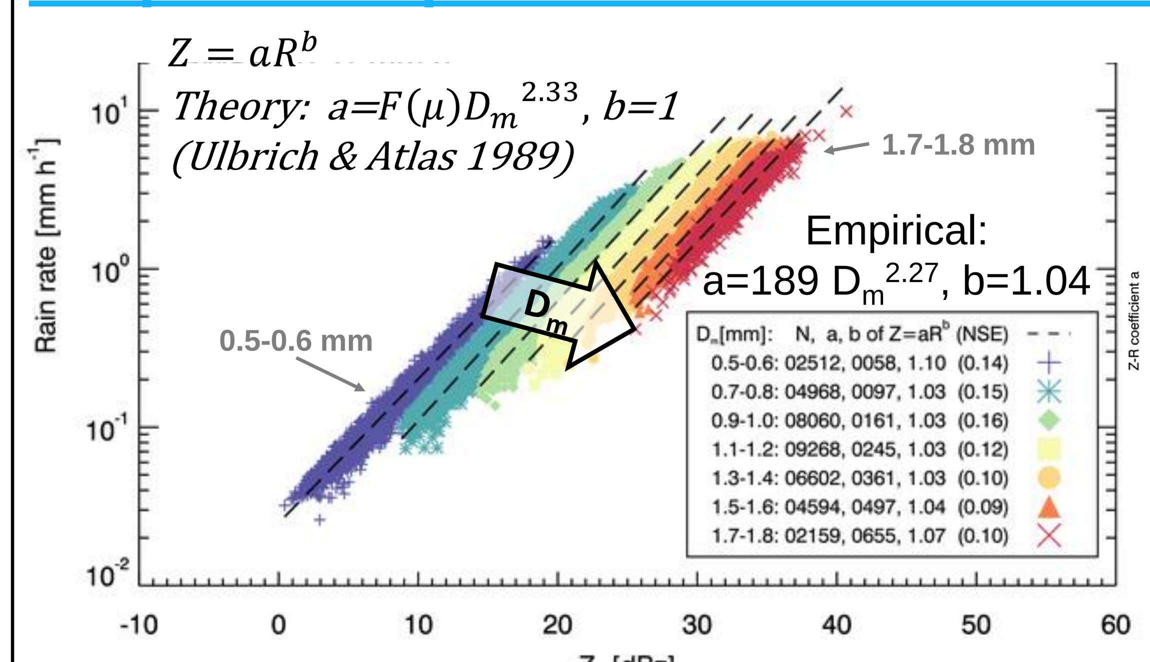
	RMSE	Relative Error
$\widehat{D_m}$	0.101 / 0.138 mm	7.9% / 12%
$\widehat{N_w}$	1374 / 3972 mm^{-1}m^{-3}	18% / 34%

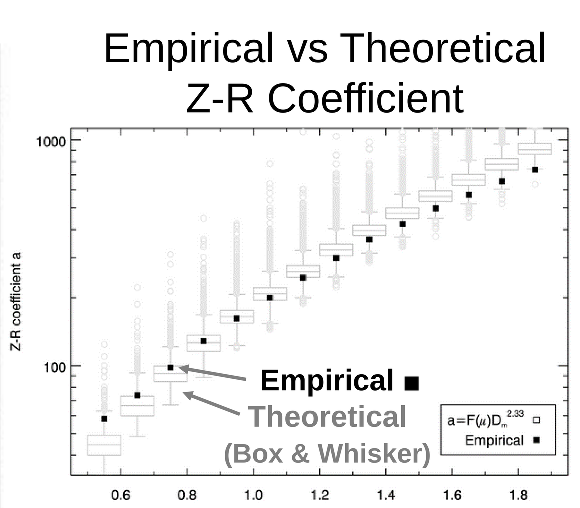


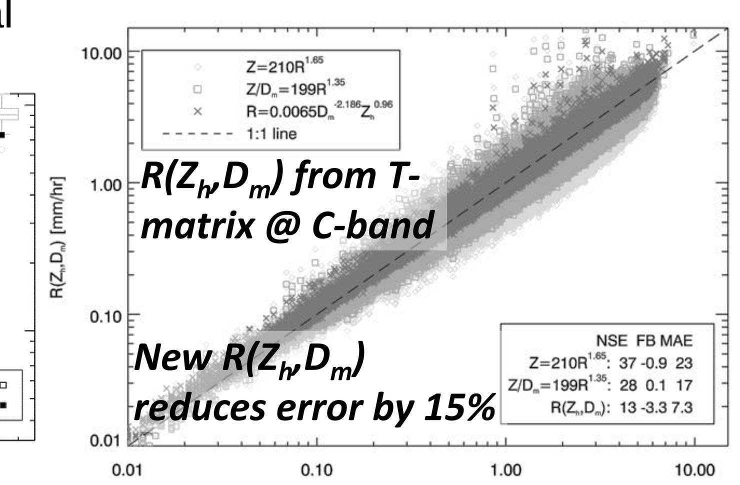
- Larger raindrops fall from thicker ML
- D_m exhibits a distinct profile
- N_w profile just below ML is more variable than it is closer to ground

→ Depth of ML can provide insight into RSD profile

Drop Size Implications for Radar QPE: A technique to further constrain Z_e



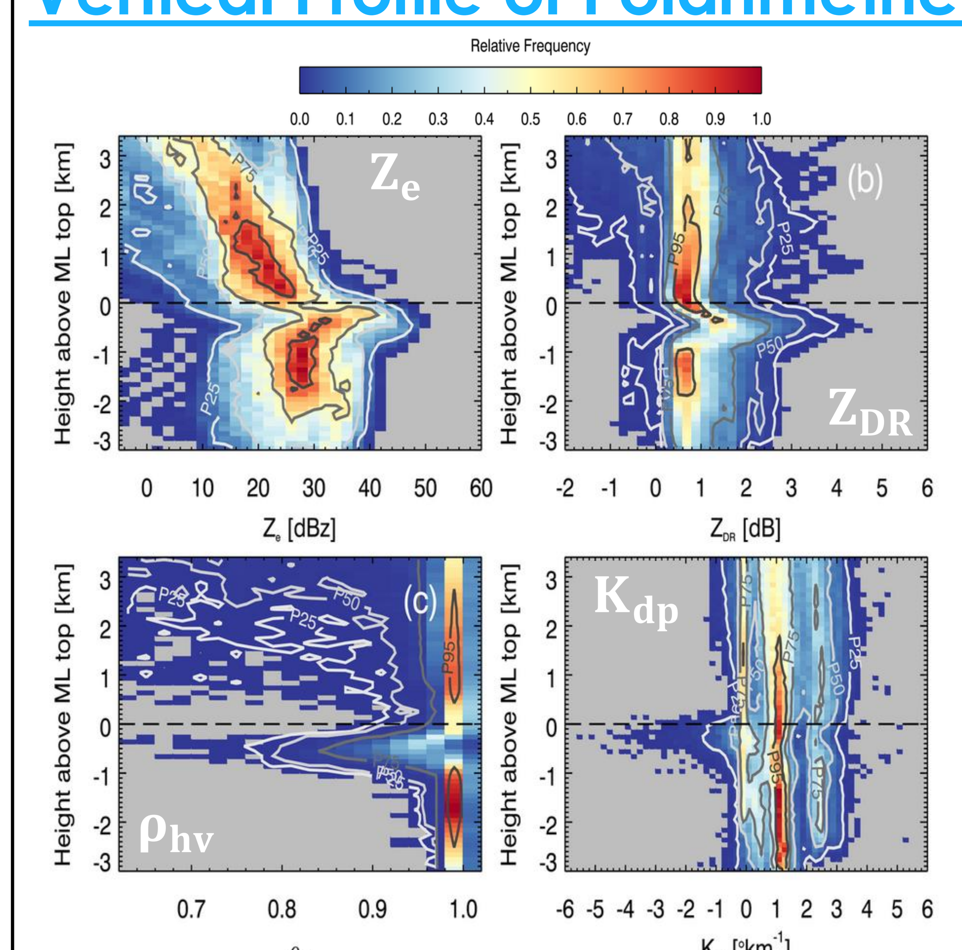


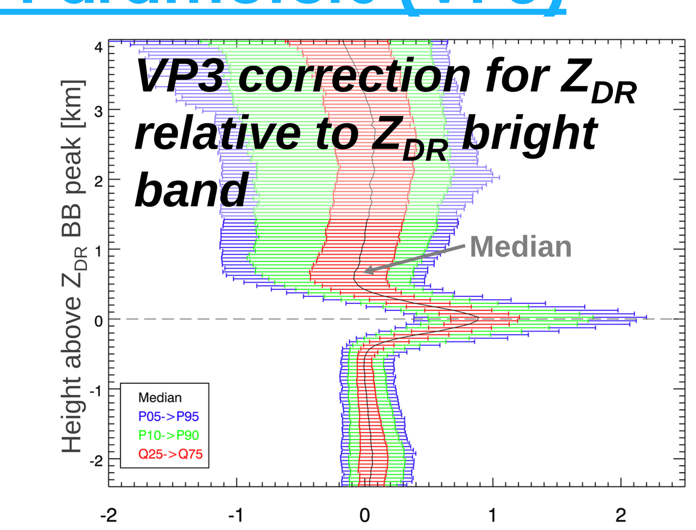


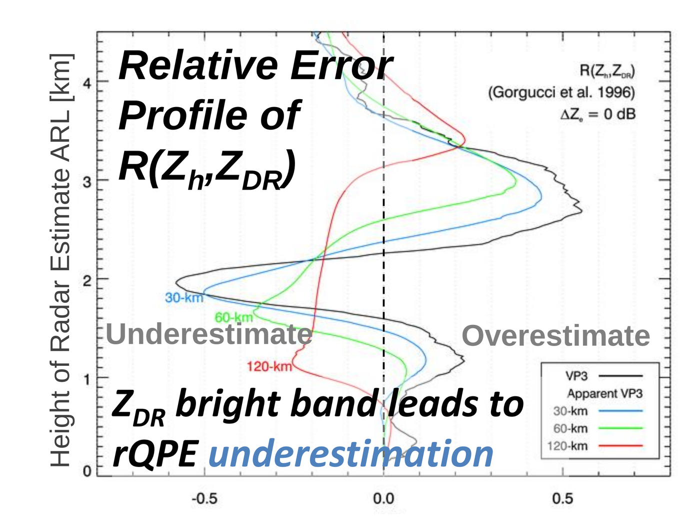
$$R(Zh, Dm) = 6.50 \times 10^{-3} D_m^{-2.186} Z_h^{0.96}$$

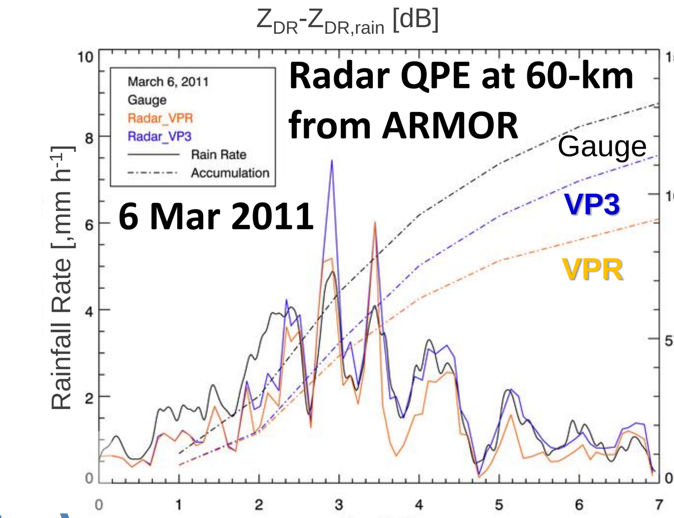
→ $R(Z_h, D_m)$ reduces error in the retrieved radar rainfall estimate

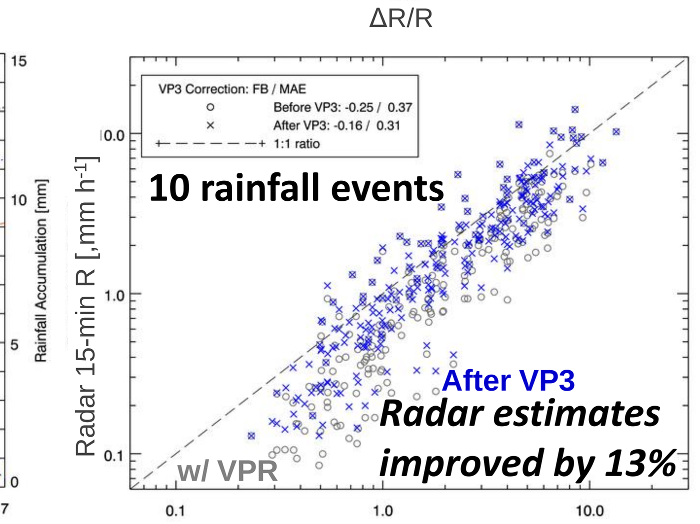
Vertical Profile of Polarimetric Parameters (VP3)











→ VP3 correction improves polarimetric radar QPE for $R(Z_h,Z_{DR})$

Acknowledgments: Funding for this research was provided by Drs. Ramesh Kakar, Gail Skofronick-Jackson, and Mathew Schwaller through NASA's PMM and GPM Programs. We would like to thank Drs. Larry Carey and Kevin Knupp for providing access to the ARMOR data and those involved with its operation. We would as well as Mr. David Wolff for providing the NPOL data from IFloodS.